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Short Term and Long Term Effects of Price Cap Regulation

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Abstract

This paper uses a very simple example (two goods, linear symmetric demand and cost) to study the effects of the price cap regulatory mechanism. We show that if a given price vector is preferred (using current welfare as the criterion) to another, then it is not necessarily the case that it is also preferred in the long run (using the presented discounted value of welfare as the criterion). The relationship between current welfare and profit and therefore the firm's incentive to bargain for a given price vector depend on the specific details of the mechanism considered.

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1 Introduction

Price cap regulation rates as one of the success stories of applied economic theory. The reason is probably the fact that it strikes a very good compromise between the theoretically rigorous foundation of the theory of optimal regulation for multiproduct firms (detailed in Jean-Jacques Laffont and Jean Tirole [12], ch.3) and the practitioner's requirement of the simple, easy-to-understand, easy-to-apply rule. Price cap regulation works in theory, because the model upon which it is based captures in an ad hoc, but nonetheless sound, fashion the asymmetry of information which is after all the very reason why regulation is needed. Price cap regulation also works in practice, because, in view of its simplicity, is applicable to situations where the regulated firm has hundreds of different prices, as can well be the case for telecommunication companies, but retains desirable properties with regard to both productive efficiency (as it does not distort a firm's incentives for cost reduction because the firm is the residual claimant of any efficiency gain), and allocative efficiency (as it reduces relative price distortions and the monopoly dead-weight loss). The success of price cap regulation is reflected in the large number of countries across the world that have adopted this principle for the regulation of multiproduct firms (OECD [13]).

A price cap mechanism has two basic, conceptually distinct, constituent elements:

- an initial price vector, and
- an adjustment mechanism.

The general principle is that, in any given period, the regulated firm can only choose prices which belong to a set of permitted prices (Michael Beesley and Steve Littlechild [5], Mark Armstrong, Simon Cowan and John Vickers [1] and Vickers [15]). In some cases, this set is independent of the firm's behaviour in the previous periods and is simply decided by the regulator at the beginning of the regulatory period. In general, it has been shown that this type of price cap has undesirable properties with respect to allocative efficiency (Ian Bradley and Catherine Price [8], Armstrong and Vickers [3] and Cowan [10] and [11]). If instead the set of permitted prices in any period is calculated using an adjustment mechanism based on the prices charged by the firm in the previous period, the mechanism is called *dynamic price cap.* We concentrated on this case in this paper.

The adjustment mechanism for dynamic price cap regulation has received a good deal of theoretical attention. An earlier analysis was carried out by Ingo Vogelsang and Jorg Finsinger [17], who proposed the following mechanism. In any period, the regulated firm is required to set prices such that, if these prices were applied to the quantities sold in the previous period, the firm would incur a loss. Vogelsang and Finsinger assume that the firm is myopic, namely that, in every period, it chooses the vector of prices that maximise its current profit under the constraint. Their main finding is that the sequence of prices chosen by the firm converges to the allocatively efficient (second best) Ramsey prices with zero profits (that is the prices where, for each good, the price mark-up above marginal cost is proportional to the reciprocal of the demand elasticity for that good and where total revenues equal total cost) (Frank Ramsey [14], Marcel Boiteaux [7] and William Baumol and David Bradford [4]).

A different mechanism is proposed by Timothy Brennan [9]. It requires the firm to set in every period of time prices such that a Laspeyres price index (which uses appropriate weights) is less than 1. This is the mechanism adopted in the typical RPI-X mechanism, adopted for the regulation of most utilities in, among others, the UK.[1] In this case also, the sequence of prices

[1] The mechanism requires the price of a given basket of goods sold by the regulated firm not to increase in a given year by more that (RPI-X), where RPI is the retail price index

charged by a myopic regulated firm converges to second-best prices that obey the Ramsey rule. The two mechanisms display very similar properties. There is, however, one fundamental difference between them. The Brennan mechanisms is such that the firm's profits increase over time, while in the Vogelsang and Finsinger mechanism profit tends to zero. This difference is reflected in the level of the prices charged by the firm in the long run, in both cases they obey the Ramsey rule, but are lower in the Vogelsang and Finsinger mechanism.

While the long-term properties are clearly important, regulators (and their principals, the politicians) are also likely to be concerned with the short term properties of the regulatory mechanism. Thus, for example, in the practical debate, much attention has been devoted to the specific reduction in the Laspeyres price index that regulated firms should be required: the X in the RPI-X formula (Jeffrey Bernstein and David Sappington [6]). Also important, in practice, is the period for which this number is fixed (Armstrong, Ray Rees and Vickers [2]).

The first element of the price cap mechanism, the initial price vector, has received much less attention. This is perhaps not surprising; from a theoretical point of view the dynamic properties of the adjustment mechanism are clearly more interesting than the "given" initial condition of the dynamical system. In practice, initial prices have typically been those prevailing at the beginning of the regulatory process, often following the privatisation of the state monopoly, when the presence of something fixed and given was probably welcome by all involved, given the host of other variables that had to be bargained over and agreed upon.

However, in industries where technological change is rapid, and where,

increase for that year and X is a number agreed at the review of the regulatory agreement. If (RPI-X) is negative, that is, for X high relative to inflation, this price of the basket of goods is, of course, required to decrease by at least (RPI-X).

for example, new products are introduced regularly, it may be necessary occasionally to "restart" as it were, the regulatory mechanism, by choosing a new, different, initial price vector. The existing theoretical literature gives little or no guidance on the consequences of choosing a new initial price vector. In this paper, we address a very simple, but important, question in this respect. Specifically, we investigate whether, given two initial price vectors, it is the case that the initial price vector which is preferable in the current period (in the sense that it gives a higher score under the chosen welfare criterion) is also preferable along the path of convergence to the Ramsey prices (in the sense that it has a higher discounted present value of the score under the same welfare criterion). We show, by means of a simple, but nonetheless robust, example, that the answer to this question is negative, both for the Vogelsang and Finsinger and the Brennan mechanisms. This may have important implications if and when initial prices are renegotiated or otherwise reset. For example, suppose that the regulated firm asks the regulators to be allowed to charge prices which (i) violate the constraints imposed by the mechanism, but (ii) are preferred (in current term) by the regulator, to the existing prices. Our simple example suggests that, contrary to what one might expect, the regulator should not, in general, allow such prices, before a more thorough analysis of their consequences is carried out. Even in the extremely simple examples we consider (two identical goods, linear independent demands, linear cost), it is possible that the regulated firm may propose a price vector that makes the regulator better off in the short term but worse off in the medium and long-term. Succinctly, prices leading to higher welfare in the short run may turn out to lead to lower welfare in the long run. More importantly, the nature of the regulatory mechanism is important in providing the firm with the incentive to propose the new initial prices: in our simple example, under the Brennan mechanism, there exist price vectors such that the firm is better off in proposing a change which makes the regulator better off in the short term but worse off in the long term. This, in our example, does not happen with the Vogelsang and Finsinger mechanism.

The plan of this note is the following: in Section 2 we describe schematically the model of dynamic price cap regulation, and in Section 3 we propose a simple example which illustrates the short and long run effects of the initial prices.

2 The General Model of Price Cap Regulation

The broad outline of the general framework for the analysis of price cap regulation is given by the following set of assumptions:

- There exist M markets which are open over an infinite number of time periods, $t = 1, ..., \infty$. In each period of time t, the M-dimensional vector of continuous and downward sloping market demand functions is $\mathbf{q} = \mathbf{q}(\mathbf{p}^t)$, where $\mathbf{p} = (p_1, ..., p_M)$ is the price vector, with p_i the price of good i, and $\mathbf{q} = (q_1, ..., q_M)$, with q_i the quantity of good i. Demand functions are invariant over time, and satisfy standard assumptions.

- A multiproduct monopolistic firm produces the M goods in each period. Production costs are denoted by $c(\mathbf{q})$, which it is assumed to be continuously differentiable and constant over time.

- The firm is myopic: in each period $t = 1, ..., \infty$ it maximises its current profits.

- Preferences of society are represented by the welfare function $W(\mathbf{p})$, which is assumed to be continuously differentiable and quasi-convex.

- The regulator agency does not have the power directly to set the prices of the goods produced by the firm, but can offer the firm a regulatory contract.

- The contract offered to the firm entails that the firm is free to choose the prices it may prefer, provided that in any period of time $t = 1, ..., \infty$ they satisfy a constraint whose general form is given by:

$$I = I(\mathbf{p}^t; \mathbf{p}^{t-1}) \Box 1. \tag{1}$$

- We denote by $\overline{\mathbf{p}}_I = \overline{\mathbf{p}}_I(\mathbf{p})$ any price vector which constitutes the limit of the sequence of prices which, in each period, maximises the current profit, subject to constraint (1), given that the initial price vector is $\mathbf{p}$. Note that this vector need not be unique, and therefore, in general, $\overline{\mathbf{p}}_I$ need not be a function.

In Vogelsang and Finsinger [17], the index I takes the following form:

$$I = V(\mathbf{p}^t; \mathbf{p}^{t-1}) = \frac{\sum_{i=1}^{M} q_i(\mathbf{p}^{t-1}) p_i^t}{c(\mathbf{q}(\mathbf{p}^{t-1}))}. \tag{2}$$

That is, if the quantity of each good sold in the previous period had been sold at today price then the firm would not have covered its total cost. Vogelsang and Finsinger show that from any initial price vector $\mathbf{p}$, the sequence of prices charged by the firm converges to the price vector which maximises the consumers' surplus under the constraint of non-negative profits for the firm. That is, $\overline{\mathbf{p}}_V(\mathbf{p}) = \overline{\mathbf{p}}_R^0$, where $\overline{\mathbf{p}}_R^0$ are the zero-profit Ramsey prices. Under reasonable conditions, this vector is unique, implying that from any initial conditions, the mechanism is such that, in the long run equilibrium the firm earns zero profits, and consumers enjoy the highest possible welfare compatible with the firm breaking-even.

Brennan [9] relaxes some of the restrictive assumptions on the firm's technology used by Vogelsang and Finsinger and imposes a less stringent price cap constraint. In his paper, the firm faces a price cap constraint given by a standard Laspeyres price index:

$$I = B(\mathbf{p}^t; \mathbf{p}^{t-1}) = \frac{\sum_{i=1}^{M} q_i(\mathbf{p}^{t-1}) p_i^t}{\sum_{i=1}^{M} q_i(\mathbf{p}^{t-1}) p_i^{t-1}}. \tag{3}$$

From an informational point of view, (3), unlike (2), does not require knowledge of the actual cost incurred, which could be an advantage when the firm also operates in markets outside the regulator's remit, and it is not possible to check the internal cost allocation between divisions of the firm. Brennan shows that the consumers surplus is weakly increasing over time and that the sequence of prices converges to a Ramsey price vector in the long run equilibrium. However, the profits enjoyed by the firms are also increasing over time and at the beginning of the regulatory process it is not possible to predict or control the level of profits the firm will obtain in the long run equilibrium, unless, of course, the cost function is also known to the regulator. Moreover, clearly, the profit earned by the firm in the limit under the Brennan mechanism is strictly positive.

3 Long-run and short-run properties

The contribution of this note is to show that a new price vector that, in the current period improves welfare may lower it in the long term. In other words, that the relationship between short term and long term welfare is not monotonic. For the sake of definiteness, we take welfare to be given by consumers' surplus, so that

$$W(\mathbf{p}) = \int \cdots \int q_1(\mathbf{x})...q_M(\mathbf{x}) dx_1...dx_M.$$

Long term welfare $W^L(\mathbf{p})$, naturally, is given by the discounted sum of all future welfare levels. If $\{\mathbf{p}^t(\mathbf{p}^0)\}_{t=1}^{\infty}$ is the sequence of prices charged by the firm, when the initial price is $\mathbf{p}^0$, then:

$$W^L(\mathbf{p}^0) = \lim_{s\to\infty} \sum\nolimits_{t=0}^{s} \delta^t W(\mathbf{p}^t(\mathbf{p}^0)).$$

Formally we establish the following results.

Proposition 1 (Vogelsang and Finsinger mechanism). *Let the firm be subject to price cap regulation, under the constraint (2).* $W(\mathbf{p}^0) < W(\mathbf{p}_V)$ *does not imply* $W^L(\mathbf{p}^0) < W^L(\mathbf{p}_V)$

Proposition 2 (Brennan mechanism). *Let the firm be subject to price cap regulation, under the constraint (3).* $W(\mathbf{p}^0) < W(\mathbf{p}_B)$ *does not imply* $W^L(\mathbf{p}^0) < W^L(\mathbf{p}_B)$*, nor does it imply* $W(\overline{\mathbf{p}}(\mathbf{p}^0)) < W(\overline{\mathbf{p}}(\mathbf{p}_B))$*.*

In words, it is not necessarily the case that the price vector which guarantees higher welfare in the short run has also the same property in the long run equilibrium.

Note the difference between the two mechanisms: with both mechanisms the present discounted value of the welfare can be lower, but, with the Brennan mechanism, it may also happen that of the limit value of the welfare is also lower. This, clearly, cannot happen with the Vogelsang and Finsinger mechanism, given that, irrespective of the initial prices, convergence is to the price vector which has the Ramsey property and zero profit. As we will see, this affects the firms incentives to propose new prices.

To establish the results, it is sufficient to exhibit numerical examples; we take a simple example. Given our aim, the simpler the example the better: more complex situation have simpler situations as special cases, and therefore a simple example implies a more general result. Our example is also robust: there are two goods, $M = 2$, and in both markets demand is linear. The cost function is also linear and symmetric: $c(q_1, q_2) = c\,(q_1 + q_2) + F$. There is no further loss in generality in normalising demand so that $q_1 = 1 - p_1$ and $q_2 = 1 - p_2$.

Initial Prices	$W(p_1,p_2)$	$\Pi(p_1,p_2)$	Prices in the limit: $\overline{p}_I$	$W^L(p_1,p_2)$	$\Pi^L(p_1,p_2)$
$p^0 = \begin{pmatrix} 0.65 \\ 0.25 \end{pmatrix}$	0.3425	0.2550	$\begin{pmatrix} 0.12869 \\ 0.12869 \end{pmatrix}$	7.96988	0.32806
$p_V = \begin{pmatrix} 0.15 \\ 0.83 \end{pmatrix}$	0.3757	0.1166	$\begin{pmatrix} 0.12869 \\ 0.12869 \end{pmatrix}$	7.88167	0.26483

Table 1: Initial and long–term equilibrium prices and welfare measures for the Brennan mechanism when $c = .1$, $F = .05$, $\delta = \frac{1}{1+0.1}$

Initial prices	$W(p_1,p_2)$	$\Pi(p_1,p_2)$	Prices in the limit: $\overline{p}_I$	$W^L(p_1,p_2)$	$\Pi^L(p_1,p_2)$
$p^0 = \begin{pmatrix} 0.65 \\ 0.25 \end{pmatrix}$	0.3425	0.2050	$\begin{pmatrix} 0.39339 \\ 0.39339 \end{pmatrix}$	3.87860	3.19299
$p_B = \begin{pmatrix} 0.46 \\ 0.36 \end{pmatrix}$	0.3506	0.3108	$\begin{pmatrix} 0.40659 \\ 0.40659 \end{pmatrix}$	3.87185	3.44906

Table 2: Initial and long–term equilibrium prices and welfare measures for the Brennan mechanism when $c = .1$, $F = .05$, $\delta = \frac{1}{1+0.1}$

In table 1 (for the Vogelsang and Finsinger mechanism) and table 2 (for the Brennan mechanism) we illustrate[2] that if the initial price vector is $\mathbf{p}^0 = (0.65, 0.25)$ then prices $\mathbf{p}_V = (0.15, 0.83)$ (for the Vogelsang and Finsinger mechanism) and $\mathbf{p}_B = (0.46, 0.36)$ (for the Brennan mechanism) give both higher consumer welfare in the current period *and* lower consumer welfare in the long period. Note that the alternative price vector under the Brennan mechanism, $\mathbf{p}_B$, gives higher profit to the firm both in the long and in the short run; on the other hand this is not the case under the Vogelsang and Finsinger mechanism: the firm's profit is lower (both in the current period and as a presented discounted value) with the price vector $\mathbf{p}_V$.

[2] All the calculation are obtained with Maple routines, details of which are available from the authors upon request and at `http:\\www.users.york.ac.uk/~gd4/`

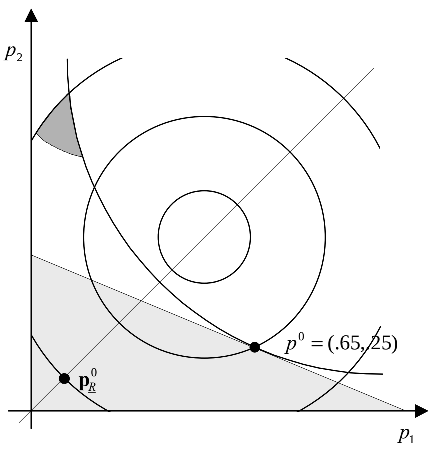

Figure 1: Price vectors which satisfy 1 -3 under the Vogelsang and Finsinger mechanism.

In the rest of the section we investigate the relationship between welfare (as measured by consumers' surplus in our example) and profit. The analysis is clearly preliminary; however, it highlights a striking difference between the two regulatory mechanisms we consider, a difference which, we believe, would carry over to more general situations.

Figure 1 depicts the $[0,1]^2$ subset of the (p_1, p_2) cartesian space. The circles are iso-profit lines, with profit increasing towards the $\left(\frac{1}{2}, \frac{1}{2}\right)$ monopoly price pair. The decreasing curve is the iso-welfare locus going through the vector of initial prices, $\mathbf{p}^0 = (0.65, 0.25)$. Welfare is, of course, higher below the iso-welfare curve (recall that welfare is consumers' surplus, and consumers always benefit from lower prices). Any price pair on the diagonal is a vector of Ramsey prices for some profit level, and the zero profit Ramsey prices are given by the round dot, $\overline{\mathbf{p}}^0_R = (.128692, 128692)$. The light grey area is the set of admissible prices according to the Vogelsang and Finsinger mechanism. The shaded set illustrates the set of points which represent combinations of prices, which, if they were chosen as alternative starting prices instead of point $(.65, .25)$ would satisfy the three conditions of

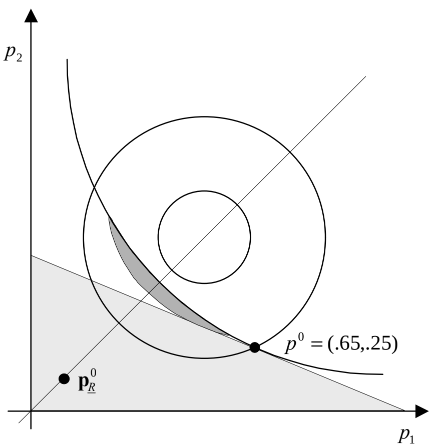

Figure 2: Price vectors which satisfy 1 -3 under the Brennan mechanism.

1. providing a higher level of current consumers' surplus (that is of being below the iso-welfare curve passing through the vector of initial prices $\mathbf{p}^0$),

2. of not being admissible according to the Vogelsang and Finsinger mechanism, (that is, of not belonging to the light grey area) and finally,

3. of providing a lower value of the discounted present value of welfare in the future, given that future price adjustments are made according to the Vogelsang and Finsinger mechanism.

As the picture illustrates, all the points which satisfy these conditions are on lower iso-profit curves than the original point. It is also the case that the present discounted value of the profit is also lower when the initial prices are given by a point belonging to the shaded set rather than at $\mathbf{p}^0 = (0.65, 0.25)$. It would therefore seem unlikely that a firm would try to suggest to the regulator that prices in the shaded set should be chosen instead of the current prices.

As the picture in Figure 2 illustrates, the situation is completely different when the Brennan mechanism is used. Here the initial prices are again

$\mathbf{p}^0 = (0.65, 0.25)$. Again the shaded set represent combinations of points which are not admissible according to the Brennan mechanism, which give a higher value of current welfare, and a lower present discounted value of future welfare. Note, however, that the firm is better off when the prices are given by points in the shaded set, which are *inside* the circle representing the iso-profit locus to which $\mathbf{p}^0$ belongs. The present discounted value of profit is also higher along the path which is followed by the prices which would be chosen by the firm starting from a point inside the shaded set and following the Brennan mechanism.

These two diagrams, therefore, would suggest radical difference differences in the behaviour of the two pricing mechanisms in the simple set up of our example; these differences are not due to any special feature of our example, and should carry through to more general examples.

Specifically, the Vogelsang and Finsinger mechanism, is such that in order for a pair of price $\mathbf{p}_V$ to give both higher current welfare and lower present discounted value of welfare than the existing prices $\mathbf{p}^0$, they must be, in a loose sense, *more distorded* from Ramsey prices than the exisiting prices: since welfare at the end of the convergence process is the same with both price pairs, and since prices $\mathbf{p}_V$ have higher welfare at the beginning of the convergence process than prices $\mathbf{p}^0$, then welfare must be lower for some intermediate period of time, when the convergence process start from $\mathbf{p}_V$. For this to happen, the convergence process must be less speedy, which occurs, as it were, when there is more distance to travel to reach the Ramsey prices obtained at the end of the convergence process.

The opposite occurs when the adjustment mechanism is given by the Brennan mechanism. Here prices which give a higher consumers' surplus than prices $\mathbf{p}^0$ are prices closer to the Ramsey prices for some profit level (namely along the diagonal, where $p_1 = p_2$). A price pair $\mathbf{p}_B$ in the shaded set is *closer* to the prices which will be eventually chosen period after period by a firm regulated according to the Brennan mechanism. This is because the prices eventually chosen depend themselves on the initial prices, unlike the prices to which the Vogelsang and Finsinger mechanism converges. By choosing prices closer to Ramsey prices the firm is able to speed up the convergence process, and therefore make it converge to higher prices, which therefore give higher profits.

4 Conclusion

We present here an exceedingly simple example, which, despite its simplicity has an important lesson for regulators. The details of the regulatory mechanism matter considerably for the achievement of the regulator's objective. Should a firm propose to restart the price cap regualtory mechanism with a different a new price it is possible that prices which are preferable from the regualtor's viewpoint when compared to the existing prices will make the regulator worse off in the long period.

In our elementary example, the firms' incentives to suggest such prices are stronger when the price cap formula is based on a Laspeyres price index, (based on Brennan's [9] original suggestion).

References

[1] Armstrong, M., Cowan, S. and Vickers, J. (1994). *Regulatory Reform.* Cambridge (MA): MIT Press.

[2] Armstrong, M., Rees, R. and Vickers, J. (1994). Optimal regulatory lag under price cap regulation. *Revista Española de Economia,* 0, Special Issue 1995, 93-116.

[3] Armstrong, M. and Vickers, J. (1991). Welfare effects of price discrimination by a regulated monopolist. *Rand Journal of Economics*, 22, 571-80.

[4] Baumol, W. J. and Bradford, D. F. (1970). Optimal departures from marginal cost pricing. *American Economic Review*, 60, 265-83.

[5] Beesley, M. E. and Littlechild, S. C. (1989). The regulation of privatised monopolies in the UK. *Rand Journal of Economics*, 20, 454-72.

[6] Bernstein, J.I. and Sappington D.E.M. (1999). Setting the X factor in price-cap regulation plans. *Journal of Regulatory Economics*, (1) 5-25.

[7] Boiteux, M. (1956). Sur la gestion des monopoles publics astreints à l'équilibre budgétarie. *Econometrica*, 22, 22-40. English version: (1971). On the management of Public Monopolies subject to budgetary constraints. *Journal of Economic Theory*, 3, 219-240.

[8] Bradley, I. and Price, C. (1988). The economic regulation of private industries by price constraints. *Journal of Industrial Economics*, XXXVII, 99-106.

[9] Brennan, T. J. (1989). Regulating by capping prices. *Journal of Regulatory Economics*, 1, 133-47.

[10] Cowan, S. (1997). Price-cap regulation and inefficiency in relative pricing. *Journal of Regulatory Economics*, 12, 53-70.

[11] Cowan, S. (1997). Tighter average revenue regulation can be worse than no regulation. *Journal of Industrial Economics*, XLV, 75-88.

[12] Laffont, J.-J. and Tirole, J. (1993). *A Theory of Incentives in Procurement and Regulation*. Cambridge (MA): MIT Press.

[13] OECD (2000). *Economic Outlook no. 67*. Paris: OECD.

[14] Ramsey, F. P. (1927). A contribution to the theory of taxation. *Economic Journal*, 37, 47-61.

[15] Vickers, J. (1997). Regulation, competition, and the structure of prices. *Oxford Review of Economic Policy*, 13 (1), 15-26.

[16] Vogelsang, I. (1989). Price cap regulations of telecommunications services: A Long-Run Approach. in Crew, M. A. (ed.). *Deregulation and Diversification of Utilities*. Boston: Kluwer Academic Publishers.

[17] Vogelsang, I. and Finsinger, J. (1979). A regulatory adjustment process for optimal pricing by multiproduct monopoly firms. *Bell Journal of Economics*, 10, 157-71.